Infrastructural Competence

Steve Sawyer, Ingrid Erickson,
and Mohammad Hossein Jarrahi

We focus here on relationships workers have with information infrastructures (Erickson and Jarrahi 2016; Henningsson and Hanseth 2011; Jackson et al. 2007), particularly as they move about between locations and institutions as part of their working. In doing so, these workers rely on stores of knowledge that allow them to continue moving forward—both figuratively and literally. These knowledge workers exist within a professional landscape that is increasingly expansive (i.e., globalized, interorganizational) and decomposed (i.e., expertise driven, project based), and we assert that this knowledge not only is becoming highly individualized, but also is progressively more elemental to what it means to be a knowledge worker (National Academies of Science 2017; Spinuzzi 2015; Barley and Kunda 2006; Davenport 2005).[1]

We articulate the stores of knowledge that workers draw on as a form of "infrastructural competence." This idea builds on Star and Ruhleder's (1996) contention that infrastructures are sociotechnical entities, comprising not only a set of interdependent technical elements but also the social layers of norms and knowledge that make these technical elements function in situ. It also builds from the work of the late Claudio Ciborra (2000) and his concept of bricolage, or the making-do practices people use to ply resources at hand toward desired goals.

These conceptual foundations reflect both the scholarly influence of science and technology studies (STS) and the contributions of organizational scholarship (where the authors situate our work, straddling the two intellectual communities). Within organization studies, there has been a constant focus on the roles of information and communication technologies (ICT) as means and mechanism for replacing human effort, automating work, and reducing both errors and tedium. The STS influence has led many organizational scholars to contest this naïve utopianism with empirical understandings of the conditionality of computing's roles (e.g., Zuboff 1985). In the case of certain kinds of work, such as clerical and administrative tasks, for example, the introduction of ICTs served to "informate" rather than liberate, simultaneously creating a class of worker whose agency was stripped by the demands of the database or the data entry field. In this chapter we argue from this analytical position, building out the idea of "infrastructural competence" with both critical and empirical insight.

Given this chapter's focus, it is useful to contextualize some of the complex conditions that help to shape contemporary forms of knowledge work. At the technological level, the rising prevalence of (and reliance on) mobile devices in professional practice has increased communication flexibility while also expanding

expectations of availability and the speed of response (e.g., Mazmanian et al. 2013; Mazmanian and Erickson 2014; Wajcman et al. 2009; Wajcman 2014). Mobile computing technologies have also helped to hasten the dissolution of work/life boundaries and contributed to the belief that life appears to be speeding up (Wajcman 2014). Cloud-based computing infrastructures make it possible for workers to decouple device-application pairings (i.e., Excel spreadsheets can run on a Windows PC and on any number of smartphones, accessing the file stored in some cloud-based storage service) and reassemble individuated ensembles that they find personally effective. As such, cloud services like Google Docs and Dropbox have become infrastructural satellites around which workers now orbit, connecting and reconnecting in different assemblage patterns as each specific situation demands.

At the socioeconomic level, knowledge work is also being reshaped. The globalization of work, a shift that began many decades ago, has resulted in an expanded network of actors and institutions upon which knowledge work must be executed today (e.g., Leonard et al. 2014). The normalcy of these international, interorganizational collaborations accords a diverse array of boundaries that must be negotiated—organizational, cultural, temporal, linguistic, legal, and so on. At the same time, these arrangements have instantiated a new logic for teamwork built ever more on specialized, rather than localized, forms of expertise. Coupled with this demand for expertise is the rising standardization of a project-based economy, an organizational structure in which specialists can be efficiently leveraged.

The ways of working have also been evolving, and the current primacy of project-based work not only has increased the shift to specialization among workers, but also is one of the forces underpinning today's "gig economy" and its related dependence on freelance or contract workers. Global platforms such as Mechanical Turk and Upwork reify the identity of knowledge workers as itinerant experts who move from one project to the next as they amalgamate a career. In some ways, the rising recognition of expertise in knowledge work has been the undoing of work itself, as workers are now more valued for their skills than they are for their humanity.

In all, these shifts in the sociotechnical and socioeconomic landscape of knowledge work amount to an unsated need for workers to be productive anytime, anywhere irrespective of context and location (e.g., Czarniawska 2014; Kleinrock 1996; Pittinsky and Shih 2004). For many workers, this may mean an opportunity to exercise agency, but it also implies the parallel imperative to manage all of the components of our productivity individually. What are the connotations of this demand?

A Model Modern Worker: Kaylie, the Realtor

Consider one example of today's mobile knowledge worker (and increasingly, doing so provides us a window into tomorrow). She is an agent of her own destiny as her goal is to excel at her job—whatever its form (e.g., contract worker, independent worker, full-time employee). In order to do this, she has to manage herself to achieve maximum performance across all of the contexts and situations in which (or through which) her work takes her. She might look something like Kaylie, a successful (by which we mean well paid) real estate agent.

We begin with Kaylie's car, a Subaru, that is clean, inside and out, which is rare enough in snowy, road-mucky Syracuse that it deserves notice. In the 22 years that she's been a Realtor, Kaylie's car choices have changed. It used to be that the back seat was the most critical feature because clients were always getting in and out. Now, her focus is on the car's front seat: she needs to see her laptop, printer, and chargers on the swiveling work desk she had installed after market. Clients no longer get in her car so that she can drive them around; instead, she meets them at the specific houses they have identified via online searches. More broadly and for the purposes of this chapter, the car is not the focus, but the means for mobility.

Kaylie is active on several local media spaces. Indeed, Kaylie is active enough online that she now outsources the work of maintaining her substantial web presence—posting pictures, videos, and other details of her realty listings along with a set of news feeds culled from various sources like the county tax office and a mortgage rate source, among other things—to someone else. A two-person company that specializes in listing houses for sale posts and updates Kaylie's residential links. Kaylie also works with three assistants: two help her to show houses, one focuses on helping clients ready homes for closing.

Kaylie is always on the phone, talking. She texts using Siri and takes voice notes. She is also always taking photos, sharing them with her network of lawyers, clients, contractors, mortgage brokers, the two-person team staging her listings, and her web people. Kaylie controls her own calendar, but it also remains visible to some of her most trusted staff and professional associates; access seems to be granted depending on trust—most of her staff do not has access, but very few contractors do.

Kaylie is always on the move. She always arranges to meet in places that are on her way from one location to another. Sometimes we simply talk in the car, though I am in the back seat—as noted, the front passenger seat is for her laptop and printer, and the foot well is where she stacks her files and papers. Kaylie puts about 25,000 miles on her car per year, but never leaves the county and rarely takes a trip of more than 10 miles.

From her car/office, Kaylie can copy, print, scan, email, and carry out document preparation through a common program that keeps all real estate forms preloaded, ready to be populated, printed, and shared digitally. Faxing signed papers is still required for some legal realty matters, and Kaylie is able to do that from her car as well. She keeps two old phones in her glove compartment and uses one or the other when her usual phone dies (something I've never seen happen). She also keeps backup batteries, phone chargers, and the like stuffed into several "cubbies" and pockets in her car, home, purse, and gym bag. Power matters.

During one of our recent meetings, Kaylie fielded 14 calls, sent dozens of text messages and emails, enlisted me to scan and send some papers for her, finished paperwork while I bought us coffee, and bumped into one of her contractors. We also were able to swing by her dry cleaner and run an errand to the drugstore. She dropped me at my home as she headed off to Curves for a workout class she never misses. Kaylie is always talking, noting that it is pretty quiet in her home in the evenings as by that point she is "talked out." Kaylie is an early riser and uses the 4:30 to 6:30 AM timeslot, before her spouse wakes up, "most days" to write her blog posts. For Realtors like Kaylie, "most days" include weekends, which tend to be busier. Wednesday and Thursday are her quieter days.

Kaylie's case provides us the means to unpack a concept that we are calling *infrastructural competence*. We advance infrastructural competence as an individual's

use-oriented relationship with infrastructures that combines social abilities, goal orientedness, and leveraging of digital and material resources in a way that enables one to generate a functional, operable, and patterned or routinized (while also being personalized) set of sociotechnical practices to accomplish a necessary task or set of tasks.

With the rest of this chapter, we situate infrastructural competence as a frame that empirically illuminates new types of knowledge work practices but, in doing so, also questions the implications of this competence as a new imperative for workers of the future. In doing this, we draw on interviews with more than 50 knowledge workers located in New York (and primarily in New York City) and the Research Triangle Park area of North Carolina. These interviewees represent a variety of occupations such as architects, consultants, web designers, and salespeople, yet what bonds them as a group is that they are all engaged in work that requires them to be highly mobile. We have chosen these "mobile knowledge workers" to build our case for the idea of infrastructural competence because these professionals largely represent an extreme version of the modern knowledge worker—embedded in expertise-driven, project-based work and heavy users of cloud-based mobile infrastructures. In short, we posit that the case of mobile knowledge workers will help not only to explicate our ideas of infrastructural competence, but likewise to uncover how deft infrastructural use may be morphing into a required element of all types of work in the near future.

From Infrastructure Use to Infrastructural Competence

The mobile workers with whom we spoke all leverage interconnected digital ecosystems, increasingly cloud-based, to accomplish their work. Analytically, we refer to these digital ecosystems as "knowledge" or "information" infrastructures (e.g., Edwards et al. 2007; Pipek and Wulf 2009). However, unlike the large-scale cyberinfrastructures used in the sciences, the knowledge infrastructures in use by the knowledge workers in our study rarely have a recognizable installed base (Monteiro et al. 2014). This is primarily due to the fact that the demands of these workers are broad and vary from person to person. Moreover, this lack of an installed base derives from the fact that there are so many possible tools available to the modern knowledge worker. The key in understanding these infrastructural patterns, thus, lies less in the way a specific installed base learns to accommodate communal changes and more in the patterned ways that workers develop functional, personalized instantiations of infrastructure for immediate use.

Infrastructures, when considered as vernacular assemblages of software, hardware, and related technological artifacts (Hanseth et al. 1996), belie their configurational natures—configurations that either "move with the worker or are found in the places in which the worker moves" (Davis 2002, 69). Indeed, for mobile workers, infrastructure is often highly visible (e.g., Rossitto et al. 2014). As they move between offices or from building to sidewalk, the digital assemblages they create are at once scripted and dynamic: specific parts are uniquely geared toward narrower task(s), but the whole is able to shift and change over time as professional needs continue to arise and dissipate (e.g., Sawyer et al. 2014; Ribes and Polk 2014). When these infrastructural scripts are tested, infrastructural seams (Vertesi 2014) are revealed. Evident seams or boundaries can be physical, in terms of geog-

raphies and companies, as well as virtual, in terms of suites and platforms of preferred ICTs.

Mobile workers relate to infrastructure in a different way than workers in more static environments (Erickson et al. 2014; Ciolfi and de Carvalho 2014; see also Plantin et al. 2016). In traditional workplaces, infrastructure, if working effectively and as designed, tends to be invisible (Pipek and Wulf 2009). For mobile workers, alternately, infrastructures are often starkly visible. As they move from one place to another or from building to street, for example, the limits of their vernacular infrastructures begin to show—one piece may work well in one context and not another or infrastructure can fail altogether in other environments. It is not that mobility forces infrastructural breakdown, rather that it raises illuminates infrastructural seams (Vertesi 2014) or contextual boundaries (Cousins and Robey 2005). Evident seams or boundaries can be physical, in terms of geographies and companies, as well as virtual, in terms of suites and platforms of preferred ICTs.

Consider the case of Monica, an architect in New York City who is building her own consultancy. Because she is engaged in a lot of business development, Monica must traverse the city quite extensively on a daily basis. It is not uncommon for her to meet clients in their offices (as the demands of her expertise are often such that being "on site" is a critical part of her problem-solving process), attend and organize professional lectures and meet-ups for the architectural community, and work with a revolving set of interns at a coworking place where she shares a small office. There is nothing necessarily unusual about this scenario upon hearing it, but look a little more closely at the multiple contexts in which Monica must perform on a daily basis and you begin to see that she is regularly traversing multiple boundaries—temporal, spatial, social, institutional, and digital (Cousins and Robey 2005; Kietzmann et al. 2013; Koroma et al. 2014). She has a strong incentive to maintain connected to her clients and coworkers as she traverses the city; she also has a strong incentive to do this as smoothly as possible because any gaps or breakdowns will reflect poorly on the professional reputation she is working hard to build. Despite this suite of sociotechnical challenges, she manages all of these traversals quite agilely. Is this merely infrastructural use or something more? We would suggest that her agility is made possible by her infrastructural competence.

Infrastructural Competence: Artful Uses of Infrastructure

We define *infrastructural competence* as an individual's use-oriented relationship with infrastructure that enables him or her to generate a functional, operable, personalized, patterned, or routinized set of sociotechnical practices that accomplish a necessary task or set of tasks. The knowledge puts infrastructure into action in such a way that draws together social norms, goal directionalities, and the particularities of digital and material resources at hand.

In keeping with recent discussions of infrastructural generativity, Monica's agility with infrastructure is not just (or even mostly) about her ability to use ICTs well. And we are not suggesting that workers simply need "better technical skills." Rather, we advance infrastructural competence as a perspective, a way of framing and seeing the ways in which digital and material infrastructures provide actors possibilities (Hanseth and Nielsen 2013; Johnson et al. 2014). We see infrastructural

competence as generative for those who possess it. This understanding of generativity asserts that actors who possess the infrastructural competence to recognize where productive infrastructural adjustments or interventions might be made can leverage this knowledge endlessly. They can use the seams and boundaries articulated above to achieve a goal again and again. Seen this way, Monica's agility is not just (or even mostly) about her ability to use ICTs well.

Developing the notion of infrastructural competence shifts the focus necessarily to the behaviors and practices of people. Workers actively draw together a set of digital components, colleagues, business partners, and working arrangements to support an intentional agenda—even if these elements are not located in one place or resist control. These efforts make the invisible visible—identifying, adopting, and configuring infrastructural arrangements. These actions reflect Vertesi's (2014) discussion of "seamfulness"—an idea developed in relation to distributed teams of scientists who navigate, negotiate, and integrate many disparate infrastructures to accomplish their work. Referring to these navigational, negotiated, and integrative alignments as "multi-infrastructural work practice" (Vertesi 2014, 278), Vertesi further suggests that individuals range over a spectrum of greater or lesser "ability"—or, possibly, circumstantial opportunity—to bring often conflicted sociotechnical systems (or device ecologies) into "artfully integrated" union.

Vertesi goes on to contend that the ability to achieve artful integration with multi-infrastructural environments connotes a degree of local knowledge and membership (Vertesi 2014, 270–71). Likewise, we suggest that someone with infrastructural competence must also be able to grasp the reality that one person's needed infrastructure is another's obstacle—what count as affordances or constraints in infrastructural terms are constructed out of individuals' own personal backgrounds, goals (Star and Ruhleder 1996), and moment-to-moment needs.

For example, a knowledge worker's complex use of calendaring (with different rights of access) reflects both the sociality of who she wants to share with and the technicalities of sharing (relative to the constantly evolving vagaries of Apple's Calendar, Google Calendar, and Microsoft Outlook). As such, any enacted infrastructural arrangement not only must work technically, but also must conform to social conventions, routines, and norms (as Kaylie's case helps to make clear). This aspect of infrastructural competence is made evident in the awareness of and respect for the shared expectations of work outcomes (if not necessarily processes). This awareness forces one's own "infrastructured actions" (Vertesi 2014, 267) to continually acknowledge the constellation of players who may be involved in shaping and maintaining infrastructures in use.

Infrastructural competence is visible through individual workers' patterns of action that showcase their ability to bridge and adjust to local sociotechnical and sociomaterial conditions. It can be identified by the set of routines that a person uses to address these conditions. Like all routines, these practices encode a set of recognizable "best practices," a template or genre known to both the individual and his or her collaborators that allows them to evoke a script of sociotechnical actions that helps "bound" (in the spirit of "bounded rationality") the particular details of a situation while still acting effectively and efficiently. Routines enable rapid action while lessening the need for perpetual sense making within interactions, but they lose their usefulness if they don't adapt as needed. Doing so aligns with organizational scholars like Feldman and Pentland (2003) who assert that even established patterns of action, like routines, are dynamic, constantly evolving to align with

changing conditions while simultaneously maintaining a coherent wholeness that is both externally and internally recognizable. We develop each of these points in greater detail below using an example from our ongoing fieldwork.

Infrastructure Competence Is a Use-Centered View

Vertesi's argument that scientists engage in individual, artful ways to use the multiple infrastructures that define their work suggests both that the work-arounds they produce to bridge infrastructural gaps and pair otherwise disparate parts together as a functional whole are expected and useful. In the large cyberinfrastructure projects Vertesi studies, these artful bridges and work-arounds occur continuously as infrastructures grow and evolve. In the case of mobile knowledge work, these artful interventions are more frequent, but also likely more lightweight. This occurs because the need to configure—or reconfigure—infrastructure(s) arises both in direct proportion to a person's physical mobility as well as in relation to the social arrangements in which a particular work task is situated. In most knowledge work situations, these are shifting on a daily, if not hourly, rate because of the distributed, project-based nature of the work. The dynamism of these disparate, yet oft sequential, situations forces individuals to focus on tasks as triggers for unique, in situ problem solving. In slight contrast to other conversations about infrastructural use, the individuated work-arounds and improvisations—this infrastructure-in-use focus—rely on individual technological response. What may work best for me in achieving the presenting task's goals may not be the same configured arrangement as my colleague.

Building on the use-centered and practice- or routines-oriented perspective on using infrastructure, we identify five characteristics or attributes of infrastructure competence: goal orientation, reliance on digital assemblages, enacted and operationally resilient, situated and relational, and an expectation based on professional identity. We discuss each of these attributes in the rest of this section.

Goal Oriented

Mobile knowledge workers develop the skills and abilities to assemble and leverage a digital assemblage to pursue an outcome. Our subjects are not interested in the ICTs they are using for any intrinsic or computational goals; these are resources being marshalled to the needs, ends, or goals of their work. This goal orientation leads to practicing, even routinizing, the skills learned through repeated uses. The use- or task-related orientation of infrastructural competence may connote, falsely, that infrastructural practices are merely solution-driven engineering feats. This is not at all the case.

In order for an infrastructural practice to be successful, it must not only work technically, but be socially recognized as legitimate and also be accountable to shared needs. Workers may arrange their working environment in whatever way they would like, for instance, or deploy a particular set of tools to address a problem, but at its core an active technological assemblage—like any infrastructure—must adhere to the social guidelines that define it. In reality, this often means that one cannot stray out of the bounds of a shared toolset, a common digital platform, or some other socially determined sociotechnical baseline that anchors infrastructural actors to one another.

Reliant on Digital Assemblages

Knowledge workers are dependent on the collections of digital resources they assemble, but they are neither building these resources as hackers nor thinking of themselves as computing experts. We observe that most mobile knowledge workers are in a knowledge-based profession, are well educated, possess unique skills and experiences, and are busy. The collections of commodity technologies (laptops, phones, public Wi-Fi, cloud storage, available apps) they pull together and the skills they develop to assemble this dynamic collection create a digital infrastructure to support their work. We have called these collections "digital assemblages" (Sawyer et al. 2014) in prior work. Others have called these sets "digital" or "artifact ecologies" (Bødker and Klokmose 2012; Forlano 2010), "digital kits" (Mainwaring et al. 2005), "individual information systems" (Baskerville 2011), or "constellations of technologies" (Rossitto et al. 2013).

Such collections are not "systems" in that they are neither designed nor controlled by one person, reflecting instead a multiparty, distributed, and often commodity-based set of arrangements. They are at once purposeful and ad hoc. A digital assemblage is the patterned collection of digital resources that a person brings to bear on a task or problem in order to pursue a goal or solution. A digital assemblage comprises the devices, information resources, applications and platforms, connectivity options, software and computational resources, and other systems that a person brings together for a particular use. A digital assemblage is neither an infrastructure (which is shared by many and owned by many) or a specific system (which is owned by a few even if used by many), it is a personal collection.

Our ideas here build on some of the foundations in infrastructure studies (e.g., Hanseth and Monteiro 1997; Hanseth et al. 1996; Hanseth and Lyytinen 2010; David and Bunn 1988). Without going fully into the resemblances between the digital assemblages of mobile knowledge workers and infrastructural examples in prior studies, it is important to underscore the parallelisms in our ideas. The digital assemblages contrived by the workers in our study are personal, but they are built on, shaped by, and constrained by their relationship to a preinstalled base. This pattern is consistent with the relational nature of infrastructures; different individuals are positioned differently in relation to the infrastructure based on the goals they want to achieve, and they use gateway technologies to facilitate information sharing and communication among fragmented systems and interconnect them into a single integrated system (Jackson et al. 2007). Another way to say this is that the creation of a technological assemblage is an example of "installed base cultivation" (Hanseth et al. 1996), meaning that an important aspect of infrastructural competence is learning "how to wrestle with the inertia of the installed base" (Bowker and Star 1999, 382; see also Edwards et al. 2009), or a set of given constraints, to achieve what you want to achieve.

Enacted and Operationally Resilient

This use in doing is reflected in the efforts directed at keeping all the elements of a digital assemblage working together. Doing so requires substantial micro-innovation to learn, problem solve, adapt, and be productive. People develop redundancies and work-arounds through trial and error, and they measure new devices, platforms, and other digital resources relative to their operational usefulness and reli-

ability. It is a pragmatic and evidence-based use, visible in the stories of Monica above as well as those of many of our other interview subjects. In essence, enacting operational resilience is what brings the digital assemblage and goals together.

Situated and Relational

This characteristic of infrastructural competence is reflected in these workers' skills and abilities to balance goals, dependencies, resources (such as what the digital assemblage can enable), and priorities. We have observed that mobile knowledge workers are able to maintain situational awareness across several tasks and to leverage their digital resources to support multithreading. Such activities reflect an expertise, an ability to "riff" on routines (adapting) and balance competing goals and issues, that appears as a distinct set of skills beyond their particular and specific expertise and professional knowledge. In this way, nomadic workers have a common set of skills related to their mobility, even as they are not professional colleagues, in the same profession (or even aware of one another's existence). They share the experiences and skills of being mobile.

A Professional Expectation

More broadly, infrastructural competence reflects an expectation by others that the mobile workers can perform their role (as professionals, in this location, as needed). As such, infrastructure competence reflects social accountability: what others expect of you regarding acceptable professional behavior, norms of connection and availability, and knowledge base. This relates to the way that one learns to enact infrastructure as a member of a community (Sandvig 2013). In this way, the social environment (e.g., a particular professional, social, or cultural community) articulates and perpetuates a common set of understandings about how certain infrastructural practices should unfold or take shape. Within the roles of actors such as real estate agents, for instance, these that can often be identified as professional routines (Pentland and Feldman 2005). In more mixed environments, these routines are solidified at the course of a collaboration engagement or as the result of certain technical requirements (e.g., privacy concerns). It is these routines that enable different people to play the same song with different instruments, at different tempos and in different keys, and sometimes with new riffs added. Difference is allowed in the expression of the routine in situ, but nevertheless the pattern is socially translucent enough among colleagues that a shared convention is identifiable and, thus, trusted. At the same time, it is imperative to note that routines are always flexible and evolving (Feldman 2000), so these patterns that serve to order sociotechnical actions are likewise ever in flux and open to updating.

Conclusion: Expectations of Infrastructural Competence

To possess infrastructural competence, then, is to recognize the goal-oriented practices that rely on smartly tuned and constantly evolving digital assemblages. These digital assemblages must be operationally resilient and are enacted in very situated and relational ways. There is an expectation by others that professional

work requires such a set of skills and resources. Seen this way, infrastructural competence reflects the stream of research that illuminates the ways in which humans (and in our particular case, workers) take up and make uses of ICT.

Some readers will see the link between these insights and the broader scholarship of STS that builds on concepts of bricolage (as noted). Some scholars may also see the partial overlap of artful doing that is at the core of infrastructural competence with the concept of articulation, drawn from the sociology of work (e.g., Strauss 1985; Star 1991). Organizational scholars might also point to Pickering's (1995) mangle of practice or the Edinburgh school's long use of "configurational technologies and learning by doing" (e.g., Fleck 1994). The value of infrastructural competence, set against these, is its attention to the artfulness of doing, the ongoing and embedded nature of this set of skills, and the inherent and evolving flexibilities of the digital and material resources, the specific situations, and the goals.

A second implication of modern workers' need to create smartly tuned digital assemblages is that doing is also a means to showcase infrastructural competence. The two are bound up: each a window to the other. To understand how digital resources are developed, deployed, and exploited is also to understand the goals, situations, and practices of the person who assembled the digital kit. Infrastructural competence is what gives rise to digital assemblages. The uses and value of digital assemblages are visible in the practices of infrastructural competence.

There is a need for more empirical work and conceptual development of this nascent concept: both to provide more clarity and precision regarding the characteristics and processes of infrastructural competence and to identify what makes a person better or worse at doing or performing competently. Both require describing and mapping local practices and the competence that emerge as these serve as bridges among various scales of infrastructure. In the specifics of our study of mobile work, what becomes clear is that more attention is needed on the intertwining of infrastructural competence and the work lives of organizations and individuals. This need to see both the work and the digital and material elements that are bound up in that effort, within the frame created by realities of large-scale infrastructures and their constitution as platforms, demands extended attention (Edwards et al. 2009; Plantin et al. 2016; Fenwick 2004).

We are acutely aware of the empirical challenges of studying infrastructural competence and see the need for methodological developments in order to better understand infrastructural competence. For example, we have valued digital images and worked to get trace data from workers' devices even as we interviewed participants, observed them, and pursued other data. Linking all of these sources of insight together and doing more to connect the digital and material aspects of mobility, while also getting more data on the multiple goals and trade-offs that mobile knowledge workers seem to pursue, are both rich and demanding empirical spaces.

Third, programmatic attention to infrastructural competence demands increased attention regarding the roles of public and organizational policies, institutional guidance and norms, training, and so forth on individuals and groups. Currently we rely on individuals (or small groups) to develop infrastructural competence on their own. If this is indeed a core element of more and more forms of work, more attention is needed to the relational nature of the conception and to the development of technologies that may advance the cause.

Fourth, we need to go beyond the observations from the outset regarding the changing nature of work to connect with ongoing research streams regarding

changes to labor force structures, the forms of organizing, and the work of macro-scale scholars such as Manuel Castells (2000, and his concept of networked societies), Peter Drucker (1969, and his prescient insights on the knowledge economy), Richard Florida (2001, with his articulation of the "creative class"), and others. These theorists might be seen as extolling knowledge work and elevating this form of work and mobility as models of the future. Harkening Neil Postman (1993), we also know that technological arrangements are only new to the generation in which they emerge. This leaves us wondering if, in a relatively short period of time, infrastructural competence will move from being a desired and differentiating characteristic of workers to being an expected and basic skill demanded from workers.

Beyond the open questions of specifics, methods, and expectations, we contribute here a new construct to the digital STS community as well as those in the burgeoning area of infrastructure studies. Our work progresses and deepens the discourse on seams within sociotechnical systems, and further contributes to our understanding of the skills and competencies that may be coming to define 21st-century work.

Note

1. "Knowledge work" and "knowledge workers" are contested terms, and we use them fully aware of this debate, as we discuss later in the chapter.

Works Cited

Barley, Stephen R., and Gideon Kunda. 2006. *Gurus, Hired Guns, and Warm Bodies: Itinerant Experts in a Knowledge Economy*. Princeton, NJ: Princeton University Press.

Baskerville, Richard. 2011. "Individual Information Systems as a Research Arena." *European Journal of Information Systems* 20 (3): 251–53.

Bødker, S., and C. Klokmose. 2012. "Dynamics in Artifact Ecologies." Paper presented at the 7th Nordic Conference on Human-Computer Interaction, Copenhagen.

Bowker, Geoffrey. and Susan Leigh Star. 1999. *Sorting Things Out: Classification and its Consequences*. Cambridge, MA: MIT Press.

Castells, Manuel. 2000. *The Rise of the Network Society*. New York: John Wiley.

Ciborra, Claudio, ed. 2000. *From Control to Drift: The Dynamics of Corporate Information Infrastructures*. Oxford: Oxford University Press.

Ciolfi, Luigina, and Aparecido de Carvalho. 2014. "Work Practices, Nomadicity and the Mediational Role of Technology." *Computer Supported Cooperative Work* 23 (2): 119–36.

Cousins, Karlene, and Daniel Robey. 2005. "Human Agency in a Wireless World: Patterns of Technology Use in Nomadic Computing Environments." *Weekly Bulletin* 15 (2): 151–80.

Czarniawska, Barbara. 2014. "Nomadic Work as Life-Story Plot." *Computer Supported Cooperative Work* 23 (2): 205–21.

Davenport, Thomas. 2005. *Thinking for a Living: How to Get Better Performances and Results from Knowledge Workers*. Cambridge, MA: Harvard Business Review Press.

David, Paul, and Julie Bunn. 1988. "The Economics of Gateway Technologies and Network Evolution: Lessons from Electricity Supply History." *Information Economics and Policy* 3:165–202.

Davis, Gordon. 2002. "Anytime/Anyplace Computing and the Future of Knowledge Work." *Communications of the ACM* 45:67–73.

Drucker, Peter. 1969. *The Age of Discontinuity: Guidelines to Our Changing Society*. New York: Harper & Row.

Edwards, Paul, Geoffrey Bowker, Steven Jackson, and Robin Williams. 2009. "Introduction: An Agenda for Infrastructure Studies." *Journal of the Association for Information Systems* 10 (1): 374–84.

Edwards, Paul, Steven Jackson, Geoffrey Bowker, and Cory Knobel. 2007. "Understanding Infrastructure: Dynamics, Tensions, and Design." Report of the NSF Workshop on History and Theory of Infrastructure: Lessons for New Scientific Cyberinfrastructures, Ann Arbor, MI.

Erickson, Ingrid, and Mohammad Jarrahi. 2016. "Infrastructuring as Appropriating in the Context of Mobile Knowledge Work." In *Proceedings of the 2016 Conference on Computer-Supported Collaborative Work*, 1323–36. New York: ACM.

Erickson, Ingrid, Mohammad Jarrahi, Leslie Thomson, and Steve Sawyer. 2014. "More Than Nomads: Mobility, Knowledge Work and Infrastructure." Paper presented at the EGOS Colloquium, Rotterdam.

Feldman, Martha. 2000. "Organizational Routines as a Source of Continuous Change." *Organization Science* 11 (6): 611–29.

Feldman, Martha S., and Brian T. Pentland. 2003. "Reconceptualizing Organizational Routines as a Source of Flexibility and Change." *Administrative Science Quarterly* 48 (1): 94–118.

Fenwick, Tara. 2004. "Learning in Portfolio Work: Anchored Innovation and Mobile Identity." *Studies in Continuing Education* 26 (2): 229–45.

Fleck, James. 1994. "Learning by Trying: The Implementation of Configurational Technology." *Research Policy* 23:637–51.

Florida, Richard. 2001. *The Rise of the Creative Class: And How It's Transforming Work, Leisure and Everyday Life*. New York: Basic Books.

Forlano, Laura. 2010. "WiFi Geographies: When Code Meets Place." *Information Society* 25:1–9.

Hanseth, Ole, and Kalle Lyytinen. 2010. "Design Theory for Dynamic Complexity in Information Infrastructures: The Case of Building the Internet." *Journal of Information Technology* 25 (1): 1–19.

Hanseth, Ole, and Eric Monteiro. 1997. "Inscribing Behaviour in Information Infrastructure Standards." *Accounting, Management and Information Technologies* 7 (4): 183–211.

Hanseth, Ole, Eric Monteiro, and Morten Hatling. 1996. "Developing Information Infrastructure: The Tension between Standardization and Flexibility." *Science, Technology, & Human Values* 21 (4): 407–26.

Hanseth, Ole, and Petter Nielsen. 2013. "Infrastructural Innovation: Flexibility, Generativity and the Mobile Internet." *International Journal of IT Standards and Standardization Research* 11 (1): 27–45.

Henningsson, Sven, and Ole Hanseth. 2011. "The Essential Dynamics of Information Infrastructures." In *ICIS 2011 Proceedings*, 1–19. New York: IEEE.

Jackson, Steven J., Paul N. Edwards, Geoffrey C. Bowker, and Cory P. Knobel. 2007. "Understanding Infrastructure: History, Heuristics and Cyberinfrastructure Policy." *First Monday* 12. https://journals.uic.edu/ojs/index.php/fm/article/view/1904/1786.

Johnson, Michael, Hajah Mozaffar, Gregoria Campagnolo, S. Hyysalo, Neil Pollock and Robin Williams. 2014. "The Managed Prosumer: Evolving Knowledge Strategies in the Design of Information Infrastructures." *Information, Communication & Society* 17 (7): 795–813.

Kietzmann, Jan, Kirk Plangger, Ben Eaton, Kerstin Heilgenberg, Leyland Pitt, and Pierre Berthon. 2013. "Mobility at Work: A Typology of Mobile Communities of Practice and Contextual Ambidexterity." *Journal of Strategic Information Systems* 22 (4): 282–97.

Kleinrock, Leonard. 1996. "Nomadicity: Anytime, Anywhere in a Disconnected World." *Mobile Networks and Applications* 1 (4): 351–57.

Koroma, Johanna, Ursula Hyrkkänen, and Matti Vartiainen. 2014. "Looking for People, Places and Connections: Hindrances When Working in Multiple Locations: A Review." *New Technology, Work and Employment* 29 (2): 139–59.

Leonard, Dorothy, Walter Swap, and Gavin Barton. 2014. *Critical Knowledge Transfer: Tools for Managing Your Company's Deep Smarts*. Cambridge, MA: Harvard Business Review Press.

Mainwaring, Scott, Ken Anderson, and Michele F. Chang. 2005. "Living for the Global City: Mobile Kits, Urban Interfaces, and Ubicomp." Paper presented at the International Conference on Ubiquitous Computing, Tokyo.

Mazmanian, Melissa, and Ingrid Erickson. 2014. "The Product of Availability: Understanding the Economic Underpinnings of Constant Connectivity." In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 763–72. New York: ACM.

Mazmanian, Melissa, Wanda J. Orlikowski, and Joanne Yates. 2013. "The Autonomy Paradox: The Implications of Mobile Email Devices for Knowledge Professionals." *Organization Science* 24 (5): 1337–57.

Monteiro, Eric, Neil Pollock, and Robin Williams. 2014. "Innovation in Information Infrastructures: Introduction to the Special Issue." *Journal of the Association for Information Systems* 15 (4): article 4. https://aisel.aisnet.org/jais/vol15/iss4/4.

National Academies of Science. 2017. *Information Technology and the U.S. Workforce: Where Are We and Where Do We Go from Here?* Washington, DC: National Academies of Science Press.
Pentland, Brian T., and Martha S. Feldman. 2005. "Organizational Routines as a Unit of Analysis." *Industrial and Corporate Change* 14 (5): 793–815.
Pickering, Andrew. 1995. *The Mangle of Practice: Time, Agency, and Science.* Chicago: University of Chicago Press.
Pipek, Volkmar, and Volker Wulf. 2009. "Infrastructuring: Toward an Integrated Perspective on the Design and Use of Information Technology." *Journal of the Association for Information Systems* 10 (5): 306–32.
Pittinsky, Todd L., and Margaret J. Shih. 2004. "Knowledge Nomads Organizational Commitment and Worker Mobility in Positive Perspective." *American Behavioral Scientist* 47 (6): 791–807.
Plantin, J., C. Lagoze, P. N. Edwards, and C. Sandvig. 2016. "Infrastructure Studies Meet Platform Studies in the Age of Google and Facebook." *New Media & Society* 10:1–18.
Postman, Neil. 1993. *Technopoly: The Surrender of Culture to Technology*. New York: Knopf.
Ribes, D., and J. B. Polk. 2014. "Flexibility Relative to What? Change to Research Infrastructure." *Journal of the Association for Information Systems*. http://aisel.aisnet.org/cgi/viewcontent.cgi?article=1675&context=jais.
Rossitto, Chiara, Cristian Bogdan, and Kerstin Severinson-Eklundh. 2014. "Understanding Constellations of Technologies in Use in a Collaborative Nomadic Setting." *Computer Supported Cooperative Work* 23 (2): 137–61.
Sandvig, Christian. 2013. "The Internet as an Infrastructure." In *The Oxford Handbook of Internet Studies*, edited by W. H. Dutton, 86–108. Oxford: Oxford University Press.
Sawyer, Steve, Rolf Wigand, and Kevin Crowston. 2014. "Digital Assemblages: Evidence and Theorizing from a Study of Residential Real Estate." *New Technology, Work, and Employment* 29 (1): 40–54.
Spinuzzi, Clay. 2015. *All Edge: Inside the New Workplace Networks*. Chicago: University of Chicago Press.
Star, Susan Leigh. 1991. "The Sociology of the Invisible: The Primacy of Work in the Writings of Anselm Strauss." In *Social Organization and Social Process: Essays in Honor of Anselm Strauss*, ed. David Maines, 265–83. Hawthorne, NY: Aldine De Gruyter.
Star, Susan Leigh, and Karen Ruhleder. 1996. "Steps toward an Ecology of Infrastructure: Design and Access for Large Information Spaces." *INFOR. Information Systems and Operational Research* 7 (1): 111–34.
Strauss, Anselm. 1985. "Work and the Division of Labor." *Sociological Quarterly* 26 (1): 1–19.
Vertesi, Janet. 2014. "Seamful Spaces: Heterogeneous Infrastructures in Interaction." *Science, Technology, & Human Values* 39 (2): 264–84.
Wajcman, Judy. 2014. *Pressed for Time: The Acceleration of Life in Digital Capitalism*. Chicago: University of Chicago Press.
Wajcman, Judy, Michael Bittman, and Judith E. Brown. 2009. "Intimate Connections: The Impact of the Mobile Phone on Work/Life Boundaries." In *Mobile Technologies: From Telecommunications to Media*, edited by Gerard Goggin and Larissa Hjorth, 9–22. London: Routledge.
Zuboff, Shoshana. 1985. *In the Age of the Smart Machine*. New York: Basic Books.